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A Hedonic Approach to Estimating the Supply of Variety Attributes of a Subsistence Crop

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ABSTRACT

The paper extends the household hedonic model, as a non-market valuation tool, by estimating a supply function for variety attributes of a subsistence crop in a developing country. The model is applied to bananas in Uganda, making use of disaggregated data on variety-specific farm-gate banana bunch prices and attributes. The hedonic analysis is applied at the farm-gate, the first link in the market chain, while accounting for the semi-subsistence nature of banana producing households. Within the framework of the agricultural household, where consumption and production decisions are non-separable, prices reflect the implicit marginal valuation of both consumption and production attributes jointly. The paper is motivated by the need to quantify the value of banana attributes in light of targeted efforts for variety improvement. Whether variety improvement will pay-off at the market level requires a more detailed examination of the relative worth of banana attributes within the structure of consumer preferences and production technologies related to bananas in Uganda. By revealing important price-attribute relationships, the findings provide guidance for future crop improvement efforts and diversification choices, while taking into account implicit market signals for output characteristics.

Keywords: hedonic analysis, agricultural household, supply, banana attributes, Uganda

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Svetlana Edmeades[1]

1. INTRODUCTION

The attributes of goods traded in markets are integral parts of market price determination. The attributes of goods, rather than the goods themselves, have also been postulated to characterize the preference structure of individuals and firms' production behavior (Lancaster 1966; Ladd and Suvannunt 1976; Ladd and Martin 1976). When objectively measured goods' attributes are mapped to observed equilibrium market prices in a competitive economy, the marginal implicit worth of output characteristics can be derived from a hedonic price function that traces the behavior of consumers and producers of differentiated products (Rosen 1974). Furthermore, with appropriate data, hedonic inferences can be extended to identify specific demand and supply functions for goods' attributes in implicit markets (Palmquist 1984; Mendelsohn 1984; Bowman and Ethridge 1992).

Applications of the hedonic price method abound, from housing and automobile markets to agricultural products. Generally, however, the hedonic model has been used to estimate relationships between prices and attributes in competitive markets in developed countries. Thus, marginal implicit prices of consumption and production attributes have typically been derived separately from either utility maximization or profit maximization frameworks, with greater emphasis given to the consumer side. To a limited extent, hedonic models have been applied to assess the marginal value of output

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characteristics of crops in developing economies (e.g., Unnevehr 1986; Dalton 2004; Langyintuo et al. 2004). While these approaches recognize the role of attributes in explaining crop product prices, there have been few attempts to estimate explicit demand and supply functions for different attributes of crops in developing economies.[2] Limited attention on the second stage hedonic analysis has partly been due to data and empirical constraints for estimating demand and supply functions. This paper contributes to the literature by extending the household hedonic model to estimate second stage marginal value functions for output characteristics of a subsistence crop in a developing economy. Estimating supply and/or demand functions for attributes provides a greater insight into the substitutability or complementarity among attributes that can result from variety improvement when evaluated at the level of market transactions. It also brings out market imperfections in the valuation of variety attributes that can induce different market-related behavior among producing households. Second stage estimation also enables the computation of *ex ante* welfare gains from trait improvement.

Several aspects distinguish the present analysis from previous applications of the hedonic model. Firstly, variety-specific crop product farm-gate prices are used in the first stage hedonic analysis. This is in contrast to the common practice of employing observed prices at the market place. Farm-gate prices trace the behavior of sellers and buyers at the first link in the market chain. This is particularly true in Uganda where most farmers who sell agricultural products (e.g. bananas, coffee) do so at the farm-gate (Edmeades 2003; Fafchamps and Hill 2005). Unlike market prices, farm-gate prices are

[2] One example is the work of Knudsen and Scandizzo (1982) who estimate demand functions for calories, as implicit attributes, in developing countries.

net of additional mark-ups and are, arguably, more indicative of the value of implicit quality characteristics of varieties sold.

Secondly, a household survey method is used to collect data for the implicit valuation of variety attributes. Each crop variety represents a differentiated product as it supplies a unique bundle of attributes. The levels of attributes are generally measured objectively in a laboratory (e.g., Unnevehr 1986; Langyintuo et al. 2004) or through experimental methods (Dalton 2004). In this paper, farmers' perceptions of variety-specific attributes are mapped to variety-specific farm-gate prices. The large number of products sold from different varieties and the heterogeneity in farmers' perceptions of variety-specific attributes provide sufficient variation to allow for attributes to correlate with price information in the hedonic analysis.

Thirdly, the second-stage hedonic approach attempts to identify the structure of consumer preferences and producer technologies that define the first stage hedonic prices within the framework of non-separable household production behavior. Producing agricultural households maximize utility not profits. They consume all or part of their own production and transact in output markets as either sellers, buyers or both. Hence, their marginal valuation of output characteristics encompasses both their consumption and production behavior.

The hedonic price method is applied to bananas in Uganda. Bananas, the staple crop of the country, are important for meeting immediate consumption requirements and for income generation of semi-subsistence households. While banana variety diversity is evident on-farm, it is also well pronounced at the market place with many different banana types sold, primarily at the farm-gate. The implicit prices of attributes are derived from three separate hedonic functions, each corresponding to a different region in Uganda. This information is pooled and then incorporated into inferences of the supply functions for specific variety attributes. Price elasticities of supply are computed for each attribute, as an illustration of sensitivities of attribute supply functions across regions.

Farmer perceptions of consumption and production banana attributes have been found to influence variety-specific planting decisions on farms in Uganda (Edmeades 2003). However, the relationship between banana attributes and market transactions is not well understood. Though there is a small number of detailed studies on banana markets in Uganda (Mugisha and Ngambeki 1994), no variety or attribute disaggregated analysis has previously been conducted for bananas. With missing markets for planting material, the implicit value of variety attributes can only be derived from observed prices of banana bunches. This paper is motivated by the need to quantify the value of banana attributes in light of targeted efforts for variety improvement. Whether variety improvement will pay-off at the market level requires a more detailed examination of the relative worth of banana attributes within the structure of consumer preferences and production technologies related to bananas in Uganda. By revealing important price-attribute relationships, the findings provide guidance for future crop improvement efforts and diversification choices, while taking into account implicit market signals for output characteristics.

2. THEORETICAL MODEL

The theoretical model draws from the theory of consumer choice (Lancaster 1966) within the framework of the agricultural household (Singh, Squire, and Strauss

1986). Intrinsic attributes of goods consumed and produced are implicit in household consumption preferences and production decisions. They are also integral determinants of prices. Prices of goods and factors of production have been derived from the maximization problem as linear functions of either input or output characteristics, separately (Ladd and Suvannunt 1976; Ladd and Martin 1976). Within the framework of the agricultural household, with consumption and production decisions often being non-separable, prices reflect the implicit marginal valuation of both consumption and production attributes jointly (Dalton 2004).

A representative agricultural household derives utility from the set of intrinsic attributes ($\mathbf{z}^c$) of crop varieties it consumes ($\boldsymbol{c}$), from other goods (x) and home time (h), given household (δ_{HH}) and local market characteristics (γ_M):

$$u(\mathbf{c}(\mathbf{z}^c), x, h \mid \delta_{HH}, \gamma_M) \qquad (1)$$

Semi-subsistence households meet their consumption requirements largely from own production. Their technology for crop production ($\mathbf{q}$) is defined by the expected levels of agronomic traits embodied in planted varieties ($\boldsymbol{z}^p$), as perceived by the farmer, and a variable input, labor (l). The production function is conditioned on physical characteristics of the farm, denoted by δ_F and market factors, γ_M:

$$\mathbf{q}(\mathbf{z}^P, l \mid \delta_F, \gamma_M) \qquad (2)$$

Consumption and production attributes, implicit in different plant varieties, are exogenous to the decision process. The vector of market characteristics is included in both the utility and production functions to reflect factors (e.g., transactions costs) affecting both demand and supply sides.

Household preferences are constrained by household budget limitations, depicted by the full income constraint, where **p** is a vector of variety-specific crop product prices, g is the price of other goods, I is exogenous income and M denotes the household full income: $\mathbf{pc}(\mathbf{z}^c) + gx = \mathbf{pq}(\mathbf{z}^p) + I = M$. The full income constraint is defined over all tradable crop products, meaning that product markets exist and households participate in market transactions for these crop products.

Input markets are often imperfect or missing, implying that production decisions are frequently motivated by endogenous shadow values of inputs. Family labor, used for production, is one example, planting material – is another. The time constraint captures the distribution of total available household time (T) between production and home activities: $T = l + h$. Planting material limitations are captured by the number of distinct varieties existing in the village (V), representing the local stock of variety attributes.

The maximization problem adheres to the household hedonic model formulated by Dalton (2004)[3], where the hedonic price function is derived as a reduced form relationship. Assuming interior solutions and summing separately over $i = 1,...,N$ consumption attributes and $j = 1,...,J$ production attributes, the following first-order conditions are formulated:

$$\sum_i \left(\frac{\partial u}{\partial c} \frac{\partial c}{\partial z_i^c} - \lambda \mathbf{p} \frac{\partial c}{\partial z_i^c} \right) + \sum_j \left(\mu \frac{\partial q}{\partial z_j^p} + \lambda \mathbf{p} \frac{\partial q}{\partial z_j^p} \right) = 0 \qquad (3)$$

[3] The derivation represented here slightly differs from the one presented by Dalton (2004). The difference stems from the fact that Dalton (2004) models consumption and production decisions as being sequential – where production decisions are made first, such that optimal input levels are determined and profit function defined, followed by consumption decisions – while in this model consumption and production decisions are assumed to be non-separable, made simultaneously.

Representing the Lagrangean multiplier for the full income constraint as the marginal utility of full income, $\lambda = {}^{\partial U}\!/_{\partial M}$, and re-arranging yields the following expression for price:

$$\mathbf{p} = \frac{1}{k}\sum_i \left[\frac{\partial u}{\partial c} \Big/ \frac{\partial u}{\partial M} \right] \frac{\partial c}{\partial z_i^c} + \frac{1}{k}\sum_j \left[\mu \Big/ \frac{\partial u}{\partial M} \right] \frac{\partial q}{\partial z_j^p} \tag{4}$$

where $k = \sum_i \frac{\partial c}{\partial z_i^c} - \sum_j \frac{\partial q}{\partial z_j^p}$, is a function of the marginal yields of consumption and production attributes in a good, respectively. The ratios in the square brackets represent the marginal rate of substitution between consumption goods and full income and production parameters and full income, respectively. As full income equals expenditure, the terms in the brackets also represent the marginal implicit price of consumption and production attributes, respectively. Therefore, output prices are functions of the product of marginal implicit prices and marginal yields of consumption and production attributes embodied in goods. Marginal yields of attributes and their marginal valuations are both assumed to be constant for each unit of good (Unnevehr 1986). Following Dalton (2004), and simplifying the notation, variety-specific crop product prices are reduced form functions of the marginal values (ϕ) and the levels (z) of both consumption and production attributes embodied in different crop varieties:

$$\mathbf{p} = \sum_i \phi_i^c z_i^c + \sum_j \phi_j^p z_j^p \tag{5}$$

Equation (5) defines the first stage hedonic approach. The second stage hedonic approach builds on the first stage by substituting with the hedonic price, **p(z)**, in the full income constraint when solving the maximization problem. Mendelsohn (1984) derives the structural demand functions for attributes within a utility maximization framework, also applied by Palmquist (1984). When adapted to the framework of the agricultural household, with non-separable consumption and production decisions, structural relationships are joint representations of the household's consumer and producer behavior[4]:

$$z_{i,j} = f(\phi_{i,j}, I, \delta_{HH}, \delta_F, \gamma_M) \tag{6}$$

where ϕ are the marginal values of *i* consumption and *j* production attributes, *I* is exogenous income and $\delta_{HH}, \delta_F, \gamma_M$ capture household, farm and market factors.

3. ESTIMATION APPROACH

The estimation approach is organized in two stages. In the first stage, a hedonic price function is estimated of observed crop product prices and the crop variety attributes. Adhering to the conceptual derivation (equation 5), the crop product price for a given variety is a function of the levels of this variety's output characteristics, including consumption and production attributes (z_i^c, z_j^p), while controlling for other market factors that may influence prices (e.g. transactions costs, bargaining power, information), denoted by γ_M. There is no rule of thumb about the appropriate functional form for the hedonic equation. Different variable transformations and model specifications have been employed in different contexts (Cropper, Deck and McConnell 1988; Freeman 1993).

[4] In a separable model, the structural demand for an attribute will typically be a function of the price vectors and demand shifters (e.g. income and other individual and household characteristics), while the structural supply of an attribute will be a function of the price vectors and supply shifters (e.g. scale of production and other bio-physical characteristics that influence the production environment). In a non-separable model, such clear cut distinction is not possible with both supply and demand shifters (δ_{HH}, δ_F) being included as factors influencing the marginal value function for the attribute.

The marginal implicit price of output characteristics is computed by differentiating the hedonic price function (5) with respect to each attribute: $\hat{\phi}_{i,j} = \frac{\partial p_a}{\partial z_{i,j}}$. This relationship gives the marginal monetary value of each attribute to the household, or an increase in the expenditure on crop product *a* required to obtain one more unit of the attribute. Desired attributes are those with positive marginal valuations, i.e. $\hat{\phi}_{i,j} > 0$. However, while $\hat{\phi}$ is a measure of the marginal implicit value of a given attribute, it does not directly reveal the underlying structure of preferences and technology that define the demand and supply functions for this attribute.

In the second stage of the estimation approach, structural equations are estimated, where the level of each attribute is regressed on the marginal implicit price of the attribute and that of other attributes, exogenous income and other explanatory variables, in an attempt to estimate the marginal value (demand or supply) function[5] for each attribute *i,j* (equation 6). Problems of identification and endogeneity typically encumber the second-stage estimation because the marginal implicit prices are functions of the same explanatory variables used in the estimation of the demand and supply functions, namely levels of attributes. The price and level of an attribute are chosen simultaneously, where the estimated marginal value function (6) and the marginal implicit price function (5) intersect, making it difficult to separate shift effects from the price-quantity relationship (Freeman 1993). Without correction for identification, second stage hedonic estimation simply reproduces the coefficients of the first stage hedonic price function without adding new information.

[5] The concept of marginal value function is used to refer to the marginal willingness to pay function (also known as demand) and the marginal willingness to accept function (also known as supply).

A feasible approach to identifying the supply/demand function for an attribute is to use information on marginal implicit prices from several spatially distinct markets (Brown and Rosen 1982; Palmquist 1984). Marginal implicit prices are typically estimated for *m* different cross-sectional markets and then pooled together under the assumption of stable preference and technology parameters across markets. The pooled data is then used to estimate the supply/demand function, identified by *m* points of intersection.

A two-stage least squares estimation procedure is recommended to correct for problems of endogeneity of marginal implicit prices in the second stage hedonic approach. Among the variables identified to be suitable instruments are dummies for different markets (i.e. different price gradients), as well as income (Bartik 1987; Epple 1987).

4. DATA

SAMPLE DESIGN

The data, collected in 2003, are drawn from a geo-referenced multi-stage random sample of banana-growing households in Uganda. The sample domain spans the major banana producing areas in Eastern, Central, and Southwestern Uganda. The sample was stratified according to elevation, with a threshold of 1,400 meters above sea level. Prior biophysical information suggests that elevation is correlated with factors contributing to variation in productivity.

A total of 27 primary sampling units were defined at the sub-county level and allocated proportionately with respect to elevation. Secondary sampling units were defined at the village level. One village was randomly selected per sub-county. A total of 20 households with access to land were selected randomly in each village. The total sample comprises 540 rural households in Uganda, of which 517 are identified as banana growers, and of the 517 banana producing households, 253 sell banana bunches at the farm-gate.

CROP CHARACTERISTICS

Uganda is one of the largest producers and consumers of bananas in the world. Bananas occupy the largest cultivated area among staple food crops in the country, with production taking place year round on small subsistence farms using low input, traditional farming methods. Bananas are a synonym for food in Uganda and are typically prepared by steaming or cooking. Several banana varieties are consumed raw as fruit; others are fermented for the production of local beer and a few are consumed by roasting[6]. The multiple end uses of bananas, as well as binding biotic and abiotic pressures, influence the mixture and number of distinct banana varieties grown, with surveyed farmers growing up to 27 different varieties simultaneously in their groves, and a sample average of 7 varieties.

MARKET PARTICIPATION AND BANANA TYPES

Bananas are produced for home consumption with excess production sold in local markets. Bananas are typically sold in bunches. The bulky nature of banana bunches

[6] Uganda is recognized as an important center of diversity for bananas. Most of the varieties grown in the country (85%) are endemic to the East African highlands and consist of two use-determined types: cooking and beer bananas. The non-endemic bananas are locally adapted varieties introduced to the country from Southeast Asia, such as certain beer and all sweet bananas. Other non-endemic types, recently introduced in the country, are hybrids from Honduras, typically considered to be multi-use varieties.

constrains their transportation to local trading centers or urban markets. Thus, the point of sale is predominantly the farm gate. All households who participate in banana markets as sellers sell banana bunches at the farm gate, with few also transacting at local trading centers. At the farm gate, transactions costs are typically borne by buyers (middle men, other farmers) and they are reflected in the level of farm-gate prices received by selling households.

The diversity of banana varieties grown on-farm is also evident in the composition of varieties sold. The majority (64%) of sold varieties are endemic to the region. Cooking varieties represent 54%, with beer varieties capturing 26% and sweet varieties representing 17% of all banana types sold, with the remaining 3% made up of multi-use and roasting banana types. While the market share for cooking banana bunches sold is comprised of 40 different cooking varieties, the number of beer and sweet varieties sold is 18 and 3, respectively. The diversity of banana bunches sold at the farm-gate is indicative of perceived differences in the combination of attributes embodied in the varieties sold.

Regional differences exist both in the composition and the share of varieties sold. While only half of all varieties sold in the Eastern and Central region of the country, the historical locus of banana production, are cooking types, in the Southwestern highland region three quarters of the sold varieties are comprised of cooking bananas, with 92% of bananas sold in this region being endemic. Cooking varieties thrive in the highlands due to lower disease pressures.

DEPENDENT VARIABLE

The dependent variable used in the analysis is a variety-specific farm-gate price elicited from farmers who sell banana bunches at the farm-gate. Farm-gate prices are calculated by variety, using the first moment of the triangular distribution of actual bunch prices received by farmers during the course of the previous year (Hardaker, Huirne and Anderson 1997)[7]. Market price data, obtained from households who purchase banana bunches, is limited and aggregated into use groups (cooking, beer, roasting and sweet banana types). With most farmers selling bunches at the farm gate, information on farm-gate prices is much richer, as it is elicited per type of variety sold, rather than aggregating varieties into use groups. Farmers are considered to be price takers at the farm-gate, competing with neighboring small-holder farmers who sell their excess banana production at the farm-gate.

Farm-gate prices trace the behavior of sellers and buyers at the first link of the market chain, conveying information about market transactions that take place outside of the ordinary market environments of trading centers in villages and markets in urban areas. This is particularly true in Uganda where most farmers who sell agricultural products (e.g. bananas, coffee) do so at the farm-gate (Edmeades 2003; Fafchamps and Hill 2005). Unlike market prices, farm-gate prices are net of additional markups and are, arguably, more indicative of the value of implicit quality characteristics of varieties sold.

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[7] Farm-gate prices for bunches sold are calculated using the first moment of the triangular distribution, $E[fgp] = \frac{(a+m+b)}{3}$, where a, m, b are the minimum, mode and maximum reported actual farm-gate prices received by farmers, by variety, in the previous year.

The survey data reveal differences in average farm-gate prices across regions, and within each region, across genomic and use groups (Table 1)[8].

[8] Ideally, information on trader characteristics, market size, seasonality, farmer information on market prices would be useful for testing the differences across prices in a given location. However, such information is not available.

Table 1--Mean of average farm-gate prices (in Ugandan Shillings) across genomic and use groups, by region

	Means* (standard deviations)			
	Region			All regions
	Eastern	Central	Southwestern	
Genomic group				
Endemic	3317.82	1692.08	2098.72	1950.21
	(198.01)	(184.68)	(135.14)	(189.36)
Non-endemic	664.09	498.19	973.49	550.14
	(146.42)	(120.21)	(119.27)	(131.57)
Use group				
Cooking	3317.81	1875.32	2277.78	2137.26
	(200.27)	(171.37)	(113.75)	(177.25)
Beer	273.14	525.26	786.97	523.52
	(62.92)	(110.77)	(89.18)	(101.94)
Sweet	940.93	608.54	1016.94	709.96
	(184.37)	(133.71)	(123.84)	(155.22)
Multi-use	979.28	458.56	2477.91	1060.20
	(76.17)	(160.91)	(91.01)	(188.25)
Roasting	5500.00	1318.39	1800.00	1477.26
	(**)	(161.22)	(**)	(142.94)

Note: *Mean values are weighted means, with weights calculated using survey sampling fractions. ** Indicates that no standard deviation exists since only one observation is recorded for this group in this region.

Banana bunches from endemic varieties capture a higher farm-gate price. Endemic varieties are considered superior in terms of their cooking quality. In the Eastern region, where disease pressures have contributed to the limited availability of cooking bananas, the farm-gate price is indicative of an implicit scarcity value of endemic varieties. Across regions, cooking banana varieties, the staple food in Uganda, are highly valued in comparison with bananas from other use groups. The high price for roasting bananas mainly reflects the large size of bunches and the fruit per bunch.

EXPLANATORY VARIABLES

The farm-gate price is used in a household hedonic model to derive the implicit value of banana output characteristics. Previous participatory research was used to select output characteristics believed to influence prices (Smale, M. and W. Tushemereirwe 2005). Among them are: one consumption attribute (quality) and two production traits (size of bunch, size of banana fruit). Farmers were asked to rate each banana variety they grow according to its provision of attributes (adapted from Reed et al. 1991). Farmers were found to differ in their subjective valuation of alternative bundles of attributes giving rise to heterogeneity in perceived attribute levels across farmers and varieties.

Quality is measured as a categorical variable (1 = bad, 2 = neither good nor bad; 3 = good), reflecting farmers' perceptions of the consumption attribute. Quality reflects the taste, color and softness of prepared food. Good cooking quality usually implies bad beer brewing quality, and vice versa. For sweet and roasting bananas, quality implies taste. A positive relationship between quality characteristics and farm-gate price is expected, as better quality is a desirable attribute.

Bunch size, measured as a continuous variable (in kilograms) was calculated from subjective yields elicited from farmers as triangular distributions (Hardaker, Huirne and Anderson 1997). The variable is constructed as the maximum expected bunch size without the presence of pests and diseases, or potential yield. Banana bunches are made of clusters of banana fruit. Fruit size and cluster distribution differ across varieties. The size of the banana fruit is measured as a categorical variable (1 = short, 2 = medium; 3 =

long). The threshold for fruit length is below 15 centimeters (for short) and above 20 centimeters (for long), as perceived by farmers. It is hypothesized that higher prices are paid for larger bunches, as well as for larger banana fruit per bunch.

Variables included in the hedonic regressions are summarized in Table 2.

Table 2--Summary statistics for dependent and explanatory variables used in the first stage hedonic analysis

Variable		Mean	St. D.
Dependent variable			
Farm-gate price*	Average price received at farm gate, by variety	1596.09	1158.52
Explanatory variables			
Quality*	Taste, softness, color (1=bad; 2=neither good nor bad; 3=good)	2.19	0.92
Bunch size*	Expected size of banana bunch (in kg)	15.57	7.14
Fruit size*	Size of banana fruit (1=bad; 2=neither good nor bad; 3=good	1.89	0.68
Time to market	Time to nearest banana market (in hours)	0.89	0.44

Note: *The means for these variables are computed over all household-variety observations (N=886). The mean of the other explanatory variable are computed at the household level (N=253 households).

Output characteristics (quality, bunch size and fruit size) are summarized across varieties. Time needed to travel to nearest banana market is also included in the hedonic function to control for the effects of transaction costs on price, as well as for other farmer-specific differences in relation to proximity to markets (e.g. bargaining power, information).

Variables used in the estimation of the supply function for each attribute are presented in Table 3.

Table 3--Summary statistics for dependent and explanatory variables used in the second stage analysis of the supply function

Variable		Mean	St. D.
Dependent variables			
Quality*	Taste, softness, color	2.19	0.92
Bunch size*	Expected size of banana bunch (in kg)	15.57	7.14
Fruit size*	Size of banana fruit	1.89	0.68
Explanatory variables			
Price of quality*	Computed from first stage hedonic price function	748.72	504.07
Price of bunch size*	Computed from first stage hedonic price function	43.60	27.93
Price of fruit size*	Computed from first stage hedonic price function	294.93	248.78
Gender	Gender of household member in charge of banana production (1=male)	0.64	0.48
Experience	Years of experience of household member in charge of banana production	11.72	11.02
Education	Years of schooling of household member in charge of banana production	5.55	3.87
Livestock assets	Value of livestock owned by the household (in 10,000's Ugandan Shl)	40.08	90.49
Household size	Total number of household members	5.79	2.64
Banana area	Area allocated to banana production (in acres)	1.16	1.71
Stock of attributes	Number of distinct banana varieties available in the village	24.02	5.95
Elevation	Household location in either low (=1) or high (=0) elevation areas	0.73	0.44
Instruments			
Time to market	Time to nearest banana market (in hours)	0.89	0.44
Exogenous income	Income received in previous year (in 10,000's Ugandan Shillings)	61.35	179.94
Eastern region	Households located in the Eastern region	0.28	0.45
Central region	Households located in the Central region	0.43	0.50
Southwestern region	Households located in the Southwestern region	0.29	0.45

Note: *The means for these variables are computed over all household-variety observations (N=886). The means of the other explanatory variables are computed at the household level (N=253 households).

Most of the explanatory variables are summarized at the household level. Among the variables hypothesized to affect the supply function are: gender of the household member in charge of banana production, reflecting preferences for attributes; years of experience in tending for the banana grove, an indicator of acquired human capital in banana related decisions; education, as a proxy for other acquired human capital; livestock assets and exogenous income, as indicators for household wealth; household size and banana production area, reflecting consumption and production scale, respectively; the number of distinct banana varieties locally available, representing the local stock of variety attributes and time taken to get to nearest banana market, as a proxy for transaction costs; and, regional dummy variables for the Eastern, Central and Southwestern regions of the country, respectively, and elevation levels, as a proxy for bio-physical conditions. The implicit attribute prices derived from the first stage hedonic analysis are also included as explanatory variables in the second stage inferences of the supply functions, and are summarized across varieties.

5. RESULTS

HEDONIC PRICE FUNCTION

Data from 253 banana producing households, who participate in banana sales, are used for the analysis. Each household sells bunches of at least one banana variety. Hence, the unit of observation is the household-variety, with some households selling bunches of up to 10 different varieties. The total of household-variety observations used in the analysis is 886.

Before estimating the hedonic price function, the farm-gate price data were tested for structural breaks associated with geographic location. The Chow test supports the existence of three regionally segmented markets for banana bunches[9]. Hence, three separate hedonic price functions are estimated, each reflecting a different geographic location (Eastern, Central and Southwestern regions). The functional form of the hedonic price function was tested for each region using a Box-Cox transformation (Cropper, Deck and McConnell 1988; Quigley and Rubinfeld 1989). For the Eastern region, the test strongly supports the log-linear specification[10]. For the Central and Southwestern regions the Box-Cox approach for testing the functional form was inconclusive and the Akaike Information Criterion (AIC) is used instead. For both regions the results of the test support the use of the log-linear specification[11]. Hence, for each region (R=*1, 2, 3*), the hedonic price is specified as a log-linear function, allowing for the joint effect of attributes on marginal implicit prices, while controlling for the effects of other market factors:

$$\log(p_a^R) = \phi_{a1}^c z_{a1}^c + \sum_{j=1}^{2} \phi_{aj}^p z_{aj}^p + \gamma_M + u_a \tag{7}$$

The marginal implicit price of quality, bunch size and fruit size in each region is computed as the partial derivative of price with respect to the attribute of interest:

$$\hat{\phi}_{i,j} = \frac{\partial p_a}{\partial z_{i,j}} = \exp(.)\phi_{i,j} \tag{8}$$

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[9] The Chow test at two specified breakpoints in the data (corresponding to three different regions) yields significant coefficient estimates: at the 1% for the breakpoint between the Eastern and Central regions ($p<.0001$) as well as for the breakpoint between the Central and Southwestern regions ($p<.0001$).

[10] The theta, the power on the price variable, was not found to be significantly different from 0 (p-value 0.893), which is an indication of the suitability of the log-linear specification of the hedonic equation.

[11] The log-linear specification of the hedonic price function was tested against the following specifications: linear, squared, cubed, square root, and inverse. For the Central region, the lowest AIC (of 614.7524) was found when using the log-linear specification. Similarly, for the Southwestern region, the lowest AIC (of 302.4638) was obtained with a log-linear specification.

The implicit value of each attribute is a function of the marginal implicit prices and levels of other attributes.

The results of the hedonic equations are summarized in Table 4, by region.

Table 4--Estimation results for the hedonic price function, by region

Variable	Eastern Region (N=249)	Central Region (N=379)	Southwestern Region (N=258)
Quality	0.74**	0.49**	0.46**
	(0.06)	(0.03)	(0.03)
Bunch size	0.04**	0.03**	0.03**
	(0.01)	(0.004)	(0.005)
Fruit size	0.34**	0.26**	0.07^
	(0.08)	(0.05)	(0.05)
Time to market	-0.26^	0.01	-0.22**
	(0.15)	(0.07)	(0.07)
Constant	4.24**	4.96**	5.72**
	(0.24)	(0.13)	(0.12)
	R^2=51%	R^2=61%	R^2=58%

Note: Standard errors in parenthesis; ** and ^ denote significance at 1% and 10% levels, respectively

Production and consumption attributes are found to jointly influence the farm-gate price of banana bunches. Better (perceived) quality, bigger bunches and larger banana fruit per bunch all increase the price received by farmers at their gates across regions. Price premiums for size and quality could have implications for farmers' preferences and the choice of varieties destined for sale. The significance of both the consumption attribute and the two production traits has a two-fold connotation. It confirms the complexity of preferences of agricultural households (driven by the simultaneity in consumption and production decisions) and signals the importance of the joint inclusion of consumption and production attributes in the hedonic analysis. This result supports existing literature that highlights potential misspecification problems when estimating household hedonic functions with only consumption or production attributes separately (Dalton 2004).

The significance of the transactions cost variable is another important result. In the Eastern and Southwestern regions, geographic isolation of farmers relative to banana markets increases the cost incurred by buyers at the farm-gate reducing the price farmers receive per bunch sold. Therefore, improvements in infrastructure (or other market impediments) could partially offset the transactions costs borne by buyers, having a positive impact on the farm-gate price of bananas.

ATTRIBUTE SUPPLY FUNCTIONS

Banana producing households are both consumers and producers of banana attributes as they meet their consumption requirements through own production, while selling excess bunches at the farm-gate. In other words, households demand attribute combinations for own consumption and they also supply bundles of attributes at the farm-gate in the form of banana bunches. Therefore, from the stand point of a market transaction at the farm-gate, the household is a seller of bunches and only the supply of attributes can be estimated using the characteristics of the selling households.

The information on marginal implicit prices of attributes, derived from the first stage hedonic analysis in the three regions, is pooled and then used in the estimation of the supply function for each variety attribute. Since the marginal implicit prices are functions of the levels of attributes and are therefore endogenous in the second stage analysis, a two-stage least squares estimation approach is used to correct for potential bias (Mendelsohn 1984). In the first stage, the estimated implicit attribute prices are regressed on all exogenous variables, including instruments. The selection of suitable instruments was guided by theory (Epple 1987; Bartik 1987) as well as by statistical tests for their validity[12]. Among the instruments used are regional dummies (representing different price gradients), exogenous income and the time to market variable. Predicted marginal prices are then included in the second stage structural regressions of supply functions of attributes, along with variables reflecting consumer preferences and production technologies:

$$z_{i,j} = f(\hat{\phi}_{i,j}, \delta_{HH}, \delta_F) \tag{9}$$

[12] Significance of pair-wise correlations between the implicit prices and variables candidates for instruments were first assessed. The selected instrumental variables were tested for relevance (using an F-test). The F-test was found to be significant for all price equations (p-value of 0.000) in the three attribute regressions, supporting the relevance of the instruments used in the estimation. Over-identification restrictions were also tested using the Hansen J statistic - test results are included in Table 5.

Results for the second stage hedonic analysis are presented in Table 5.

Table 5--Results from the two-stage least squares regressions of the supply functions, by attribute

Variable	Quality (N=886)	Bunch Size (N=886)	Fruit Size (N=886)
Price of quality	-0.0011*	-0.0043	-0.0013**
	(0.0005)	(0.0046)	(0.0004)
Price of bunch size	0.0316**	0.5123**	0.0308**
	(0.0090)	(0.0875)	(0.0074)
Price of fruit size	-0.0001	-0.0180**	0.0007
	(0.0006)	(0.0055)	(0.0005)
Gender (1=male)	0.0151	0.5190	-0.0789^
	(0.0491)	(0.5099)	(0.0449)
Experience	-0.0020	0.0128	0.0005
	(0.0022)	(0.541)	(0.0019)
Education	-0.0181**	0.0950	-0.0030
	(0.0068)	(0.0719)	(0.0059)
Livestock assets	0.0001	-0.0012	-0.00003
	(0.0002)	(0.0025)	(0.0002)
Household size	0.0095	-0.0931	0.0051
	(0.0094)	(0.0894)	(0.0081)
Banana area	0.0415^	-0.03975^	0.0050
	(0.0221)	(0.2256)	(0.0187)
Stock of attributes	0.0110**	-0.1475**	0.0056
	(0.0041)	(0.0476)	(0.0041)
Elevation (1=low)	0.1886*	9.2969**	0.0452
	(0.0972)	(1.2850)	(0.1002)
Constant	1.1462**	-2.8603	1.1140**
	(0.2265)	(2.1487)	(0.1914)
Hansen J statistic	0.207	0.799	0.387
(p-value)	(0.6488)	(0.3715)	(0.5341)
	R^2=93%	R^2=85%	R^2=92%

Note: Robust standard errors in parenthesis; **,*,^ denote significance at 1%,5% and 10% levels, respectively

Farmers who receive a higher price for quality tend to sell bunches with less of this characteristic, though the own price effect of quality is very small. The result supports the semi-subsistence nature of producing households, also indicating possible market failure to value quality characteristics. The market price for quality is perhaps lower than the household's implicit valuation of quality, which induces farmers to keep bunches with more of the attribute for own consumption and supply bunches with less of the attribute to the market. Quality is highly valued by both agricultural households and other rural and urban consumers of bananas. Higher provision of quality would thus be stimulated by prices that exceed the marginal valuation of producing households, inducing them to sell more of the characteristic. The result could also be indicative of supply behavior in light of scarcity of the attribute.

Quality and bunch size appear to be complements at the farm-gate. Farmers who receive a higher price for bunch size appear to sell bigger bunches as well as bunches of better quality. This has implications for variety improvement suggesting that the focus of improvement should not only be on agronomic traits (such as yield, measured in terms of the size of the bunch), but also on consumption characteristics embodies in varieties. Consequently, banana bunches that capture a high price at the market will be those that provide bundles of desirable consumption and production attributes simultaneously.

The results for fruit size suggest substitutability with both bunch size and quality. Higher price for fruit size reduces the supply of bigger bunches, which could be explained by efficiencies per bunch. When quality captures a higher price bunches sold have less not only of the quality characteristic, but also in terms of the size of the fruit. As suggested above, bunches with perceived better quality and larger fruit size are perhaps used for meeting household consumption requirements. When the person in charge of banana production decisions in the household is a woman, larger fruit size is sold at the farm-gate, perhaps reflecting preferences for size suitable for preparation of meals.

Among the production characteristics found to influence the supply of quality and bunch size are banana area, the local stock of attributes and elevation. Larger scale of banana production is associated with greater volume of excess bunches sold, which increases the provision of quality at the farm-gate, while reducing the weight of bunches sold. After meeting their own subsistence requirements farmers tend to sell more of the quality attribute embodied in smaller bunches. Greater availability of attributes at the village level has a similar effect to the scale of production by stimulating the provision of more quality and lower bunch size. Local abundance of varieties with good quality characteristics induces farmers to provide more of the quality characteristic at their farm-gates. Farmers in low elevation areas provide more quality and bigger bunch size at the farm-gate.

The supply of all three attributes at the farm-gate does not appear to be influenced by household and individual characteristics of farmers. This perhaps is indicative of the estimated marginal value function being indeed a supply function, as only production characteristics are found to influence the supply of attributes. The exception is the effect of formal education on the provision of quality. Although preferences for goods are constrained by full income, the supply of attributes (implicit in those goods) does not appear to be influenced by wealth (proxied by the value of livestock assets).

Price elasticities of supply are computed for each attribute, as an illustration of sensitivities of prices of attributes across regions and when compared to each other (Table 6).

Table 6--Own price elasticities of supply, by attribute and region

	Eastern region	Central region	Southwestern region
Quality	-0.44*	-0.33*	-0.39*
	(0.20)	(0.14)	(0.17)
Bunch size	1.48**	1.45**	1.69**
	(0.28)	(0.24)	(0.29)
Fruit size	0.14	0.12	0.04
	(0.10)	(0.09)	(0.03)

Note: Robust standard errors in parenthesis; **,*,^ denote significance at 1%,5% and 10% levels, respectively

They reflect the differential spatial impact (in terms of welfare) that research interventions in variety improvement might have when targeting specific attributes. The supply of bunch size is clearly elastic across regions, with higher responsiveness in the Southwestern region where production is more commercially oriented. The supply of quality is inelastic and much more so in the Central region, where biotic pressures have reduced the banana production potential, constricting the local availability of this attribute.

6. CONCLUDING REMARKS

This paper applies the hedonic price method as a non-market valuation tool for the estimation of supply functions of variety attributes of a subsistence crop in a developing economy. The hedonic price is derived within the framework of utility maximizing agricultural households who make consumption and production decisions simultaneously. This is reflected in the specification of the hedonic function to account for both consumption and production attributes jointly. By using spatially segmented information from three regions in Uganda, supply functions for three attributes were identified and estimated.

Adoption studies focus on the impact of new varieties (and their attributes) on planting decisions. This paper extends the scope of the analysis by focusing on the farm-gate, after production and consumption decisions have been made. Attribute trade-offs occur both on farm and at the farm gate and different factors influence the type and the size of attribute trade-offs at both levels. It is therefore important to assess the impact of variety improvement at both levels, focusing on the provision of different bundles of attributes on farm and at the market. The analysis provides the tools for assessing the value of a set of attributes and their relationship to each other in the preference structure of banana producing agricultural households in Uganda. The use of farm-gate prices enables a closer examination of the supply behavior of producing farm households.

Attributes such as quality, bunch size and fruit size are found to determine the price paid/received for bunches at the farm-gate, supporting the specification of household hedonic models to include both consumption attributes and production traits jointly. Reducing transactions costs to participation in banana markets may lead to higher farm-gate prices, reflecting larger premiums for quality and size. The insights obtained from the attribute supply functions, particularly the attribute trade-offs at the farm gate, have important implications for both variety improvement. Complementarities among attributes provide an indication of the value of trait improvement at the farm gate when several traits are supplied jointly. In particular, for variety improvement strategies to pay-off at the farm gate both bunch size and quality of the bunch need to be targeted jointly. The results also highlight possible imperfections in output markets in the valuation of attributes. For example, the implicit price of quality at the farm-gate may be lower then the household (reservation) valuation of quality, which reduces the provision of the attribute at the farm gate.

The type of economic agents whose market behavior is analyzed (semi-subsistence agricultural households in a developing economy) and the use of farm-gate prices, rather than prices recorded at the market place, requires the refinement of the concept of marginal valuation of intrinsic attributes. Rather than considering strictly marginal willingness to pay (a value function that traces consumer behavior) or marginal willingness to sell (a value function tracing producer behavior), the marginal value function is adapted to the framework of an agricultural household. Because agricultural households make production and consumption decisions simultaneously, no clear cut separation in their value structure is readily identifiable. They possess a marginal value for attributes which is implicit in their decisions as consumers and as suppliers and as such the value function captures their behavior as an envelope of their consumption and productions motivations. This is a conceptual issue that needs further development if the hedonic price method is to be applied to issues concerning production and consumption behavior in developing economies with imperfect input markets.

Trait valuation could also be used to link farmer supply of traits, estimated with farm-level data, to industry-level models of consumer valuation of traits in urban markets. This would enable the computation of welfare gains from (single or joint) trait improvement for different population segments in the country, providing a more aggregate assessment of the value of specific research interventions.

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